

New Strange Asymmetry Results from NuTeV

David Mason
University of Oregon

for the NuTeV Collaboration



David Mason: Moriond QCD 2004
dmason@jekyll.uoregon.edu



The NuTeV Collaboration:

T. Adams⁴, A. Alton⁴, S. Avvakumov⁸, L. de Barbaro⁵, P. de Barbaro⁸,
R. H. Bernstein³, A. Bodek⁸, T. Bolton⁴, J. Brau⁶, D. Buchholz⁵, H. Budd⁸,
L. Bugel³, J. Conrad², R. B. Drucker⁶, B. T. Fleming², R. Frey⁶, J. A. Formaggio²,
J. Goldman⁴, M. Goncharov⁴, D. A. Harris⁸, R. A. Johnson¹, J. H. Kim²,
S. Koutsoliotas², M. J. Lamm³, W. Marsh³, D. Mason⁶, J. McDonald⁷,
K. S. McFarland^{8,3}, C. McNulty², D. Naples⁷, P. Nienaber³,
V. Radescu⁷, A. Romosan², W. K. Sakamoto⁸, H. Schellmann⁵, M. H. Shaevitz²,
P. Spentzouris², E. G. Stern², N. Suwonjandee¹, M. Tzanov⁷, M. Vakili¹,
A. Vaitaitis², U. K. Yang⁸, J. Yu³, G. P. Zeller⁵, and E. D. Zimmerman²

¹University of Cincinnati, Cincinnati, OH

²Columbia University, New York, NY

³Fermi National Accelerator Laboratory, Batavia, IL

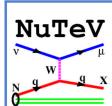
⁴Kansas State University, Manhattan, KS

⁵Northwestern University, Evanston, IL

⁶University of Oregon, Eugene, OR

⁷University of Pittsburgh, Pittsburgh, PA

⁸University of Rochester, Rochester, NY

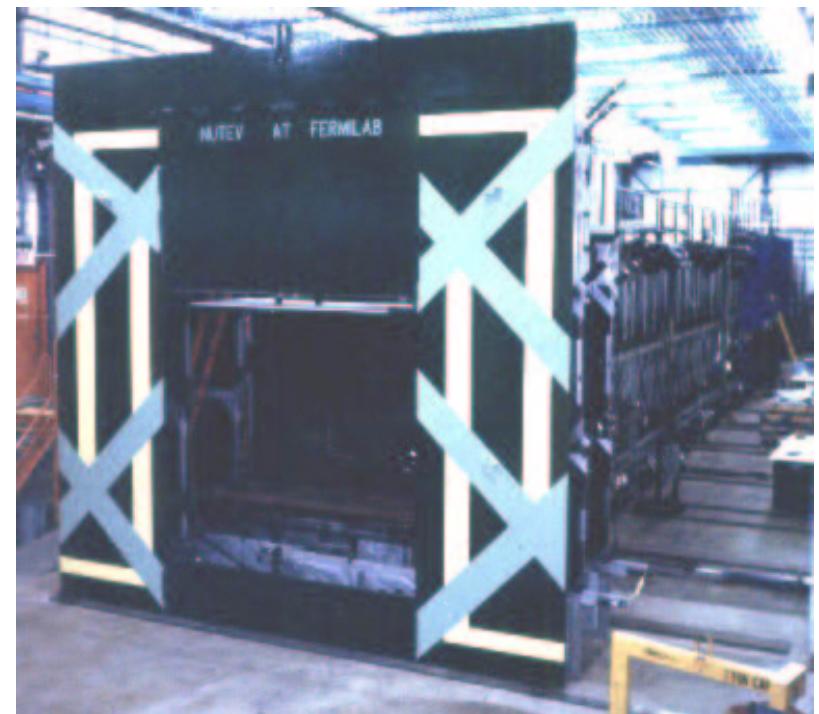


David Mason: Moriond QCD 2004
dmason@jeckyll.uoregon.edu



Some Context – What's NuTeV?

- ν -N DIS ($\langle E_\nu \rangle \sim 120\text{GeV}$)
- FNAL '96-'97 fixed target run
- Detector calibration beam throughout run
- High purity, selectable ν and $\bar{\nu}$ beams

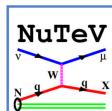
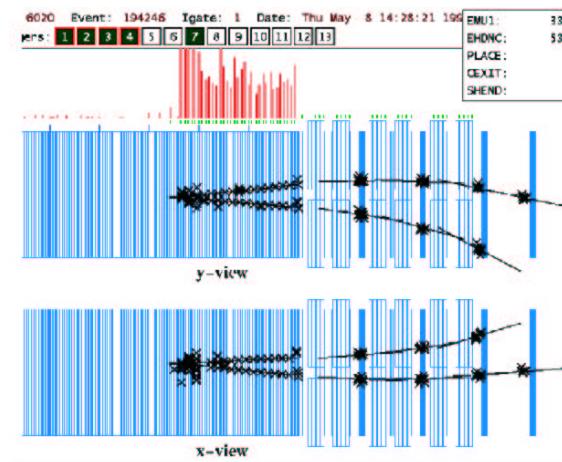
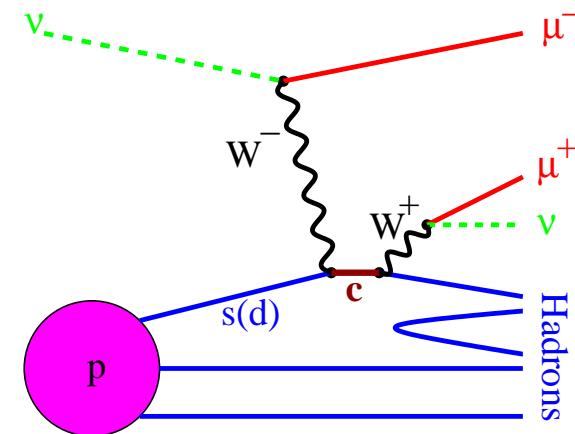


David Mason: Moriond QCD 2004
dmason@jekyll.uoregon.edu



Charm Production \Rightarrow Dimuons

- CC νN makes charm
 - fragmentation
 - semileptonic decay to μ
- Very clear signature
- Can study charm mass, fragmentation
- Direct look at strange sea
- NuTeV has unique ability to directly measure $s^- = s - \bar{s}$
- Forward cross section available for fitting
(Goncharov et al:PRD64 (2001) 112006)



David Mason: Moriond QCD 2004
dmason@jeckyll.uoregon.edu



Elements in Dimuon Cross Section Table Fit

$$\frac{d\sigma_{charm}(E_\nu, x, y)}{dxdy} \cdot EMC(x) \cdot B_c \cdot \mathcal{A}(E_\nu, x, y; \epsilon, m_c) = \boxed{\text{fit}} \Rightarrow \frac{d\sigma_{2\mu}(E_\nu, x, y)}{dxdy}$$

$$\frac{d\sigma_{2\mu}(E_\nu, x, y)}{dxdy}$$

Measured NuTeV dimuon cross section

$$\frac{d\sigma_{charm}(E_\nu, x, y)}{dxdy}$$

Calculated NLO inclusive charm cross section.
Depends on m_c , strange and antistrange seas.

$$EMC(x)$$

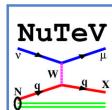
EMC correction

$$B_c$$

Semileptonic branching ratio.

$$\mathcal{A}(E_\nu, x, y; \epsilon, m_c)$$

Acceptance function due to the 5 GeV cut on the muon
from semileptonic charm decay $\left(\frac{\mathcal{N}(E_{\mu 2g} > 5\text{GeV})}{\mathcal{N}(\text{all})} \right)$.



David Mason: Moriond QCD 2004
dmason@jeckyll.uoregon.edu

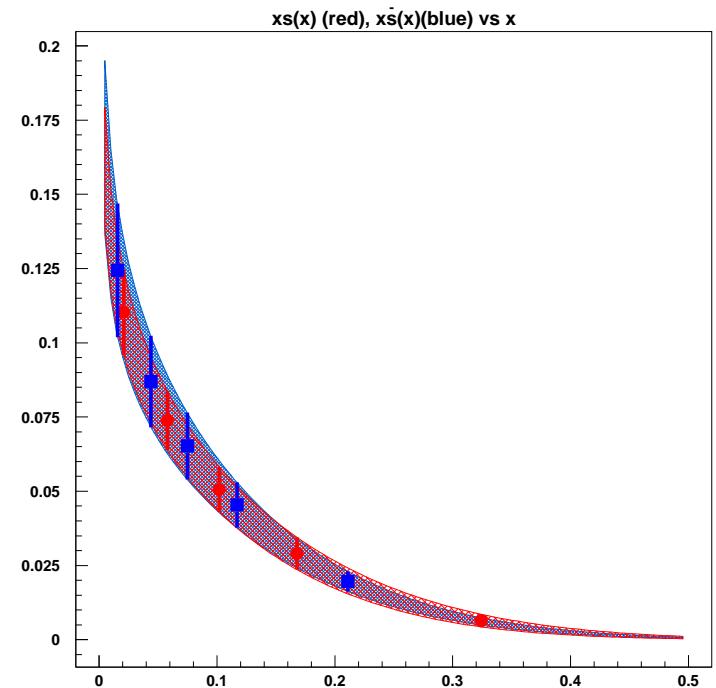


New Leading Order CTEQ5L result...

- CTEQ5L pdf set
- “Traditional” parameterization:

$$s(x, Q) = \kappa(1-x)^\alpha \left[\frac{\bar{u}(x, Q) + \bar{d}(x, Q)}{2} \right]$$
$$\bar{s}(x, Q) = \bar{\kappa}(1-x)^{\bar{\alpha}} \left[\frac{\bar{u}(x, Q) + \bar{d}(x, Q)}{2} \right]$$

- Points are evaluated at ν and $\bar{\nu}$ table data points

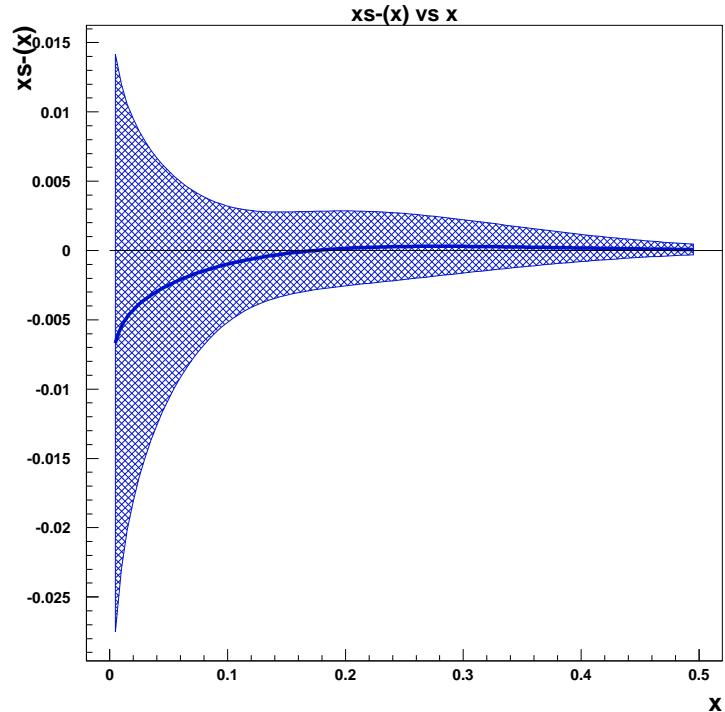


David Mason: Moriond QCD 2004
dmason@jeckyll.uoregon.edu

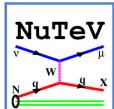


LO Asymmetry...

- $xs^-(x) = xs(x) - x\bar{s}(x)$
- Consistent with zero
- Slight trend towards negative asymmetry at low x



$$\int xs^-(x)dx = -0.0003 \pm 0.0011$$

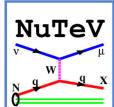
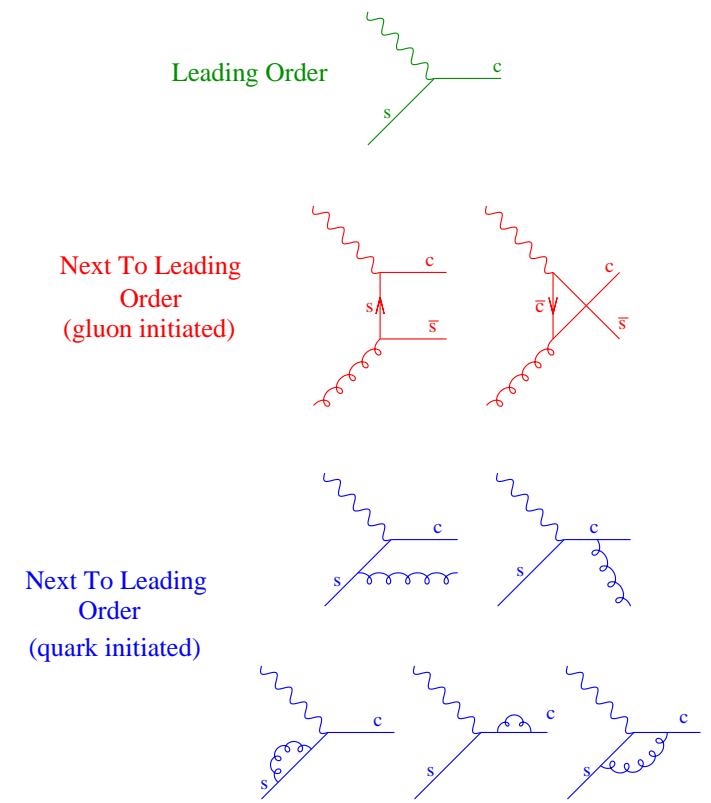
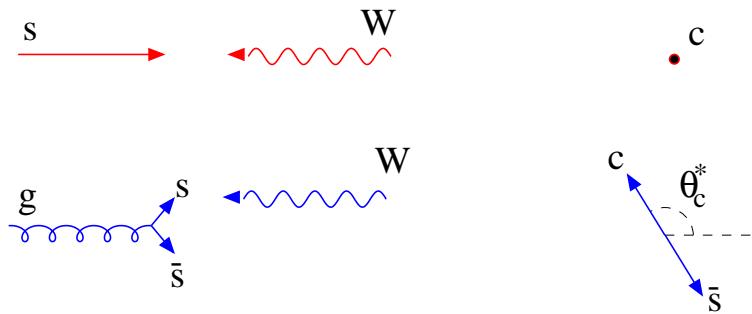


David Mason: Moriond QCD 2004
dmason@jeckyll.uoregon.edu



NLO Fits

- NLO strange sea of global interest
- Large gluon contribution
- Fragmentation requires convolution integral
- Dimuon acceptance depends on z , charm p_\perp



David Mason: Moriond QCD 2004
dmason@jekyll.uoregon.edu



New NLO Results

- NLO fits to NuTeV dimuon cross section tables
- Acceptances calculated from Monte Carlo using DISCO
(S. Kretzer, F. Olness, D.M.; PRD65 (2002) 074010)
- CTEQ6M pdf sets
- B_c fixed at E531 value: 0.093 ± 0.008
- Collins Spiller fragmentation: ϵ set to 0.75 ± 0.25
(Based on Data/MC scans vs ϵ)
- Concentrating on asymmetry – insensitive to ϵ choice



David Mason: Moriond QCD 2004
dmason@jeckyll.uoregon.edu



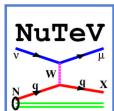
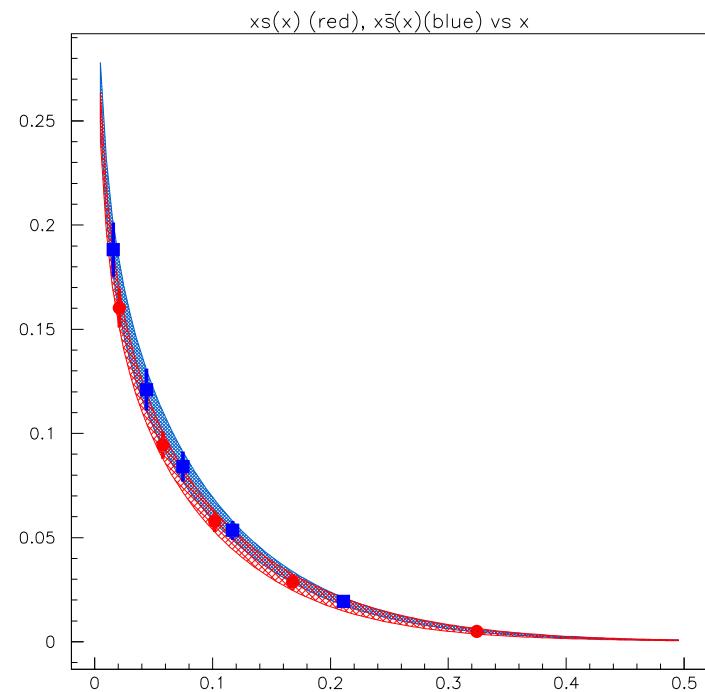
NLO Strange Sea

- “Traditional” parameterization

$$s(x, Q) = \kappa(1-x)^\alpha \left[\frac{\bar{u}(x, Q) + \bar{d}(x, Q)}{2} \right]$$

$$\bar{s}(x, Q) = \bar{\kappa}(1-x)^{\bar{\alpha}} \left[\frac{\bar{u}(x, Q) + \bar{d}(x, Q)}{2} \right]$$

- Tendency towards bigger \bar{s} at low x
- $\chi^2 = 38/39$ NDF

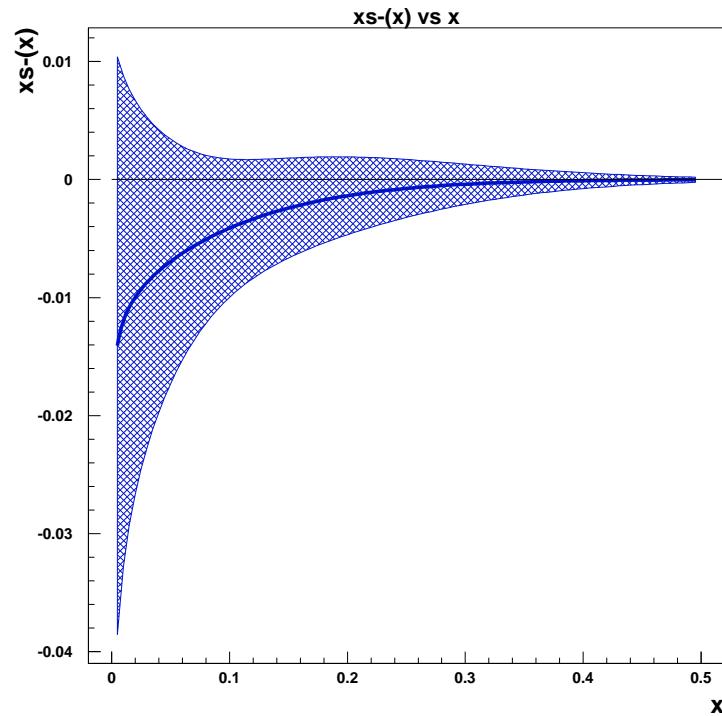


David Mason: Moriond QCD 2004
dmason@jeckyll.uoregon.edu



NLO Strange Asymmetry

- s^- similar behavior to LO.
- still consistent with zero
- again, slight negative trend
- But is this artifact of “not quite right” QCD?
- “Evolution” via $\bar{u}(x, Q) + \bar{d}(x, Q)$
- κ independent of $\bar{\kappa}$



$$\int xs^-(x)dx = -0.0011 \pm 0.0014$$

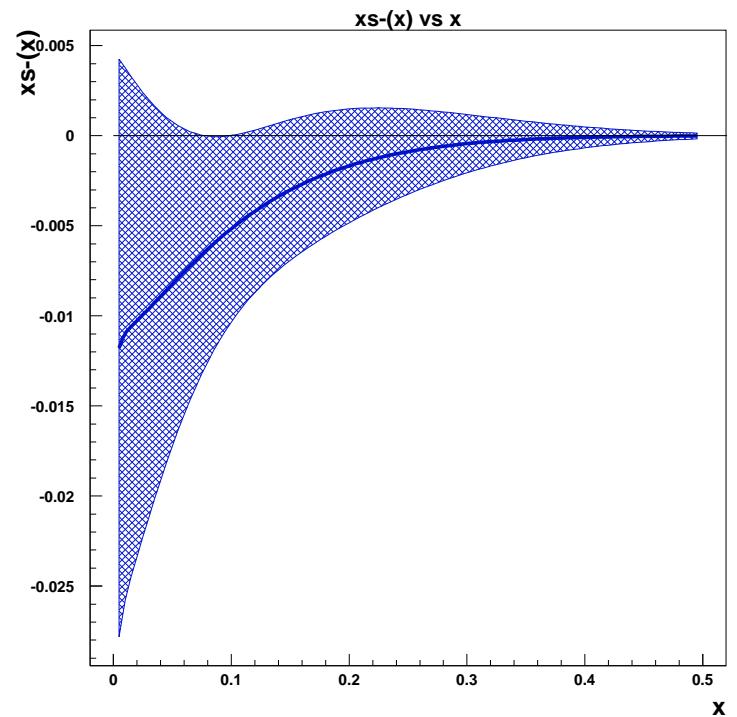


David Mason: Moriond QCD 2004
dmason@jekyll.uoregon.edu



Evolve Properly

- Multiplying evolved pdf's by function of x technically violates Alterelli-Parisi Equations
- Must define at Q_0 , then evolve
- Evolution code must let $s \neq \bar{s}$!!!
- Does it matter? \implies
- s^- has the same behavior!
- **But still don't constrain**
 $\int s^-(x)dx = 0$



$$\int xs^-(x)dx = -0.0013 \pm 0.0013$$



David Mason: Moriond QCD 2004
dmason@jeckyll.uoregon.edu

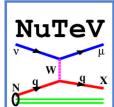


Further Satisfying QCD requirements

- Stepping up collaboration with phenomenologists (Amundson, Kretzer, Olness, Tung)
- We adopt a “CTEQ inspired” parameterization ([hep-ph/0312323](#))

$$\begin{aligned}s^+(x, Q_0) &= \kappa^+ (1-x)^{\alpha^+} x^{\gamma^+} \left[\bar{u}(x, Q_0) + \bar{d}(x, Q_0) \right] \\ s^-(x, Q_0) &= s^+(x) \tanh \left[\kappa^- (1-x)^{\alpha^-} x^{\gamma^-} \left(1 - \frac{x}{x_0} \right) \right] \\ s &= \frac{s^+ + s^-}{2} \quad \bar{s} = \frac{s^+ - s^-}{2}\end{aligned}$$

- Flavor sum rule satisfied by x_0 such that $\int s^-(x, Q_0) dx = 0$
- We choose to slightly violate momentum sum rule
- Constraining $\int x s^+$ removes valuable degree of freedom
- No effect on asymmetry or nonstrange pdfs.

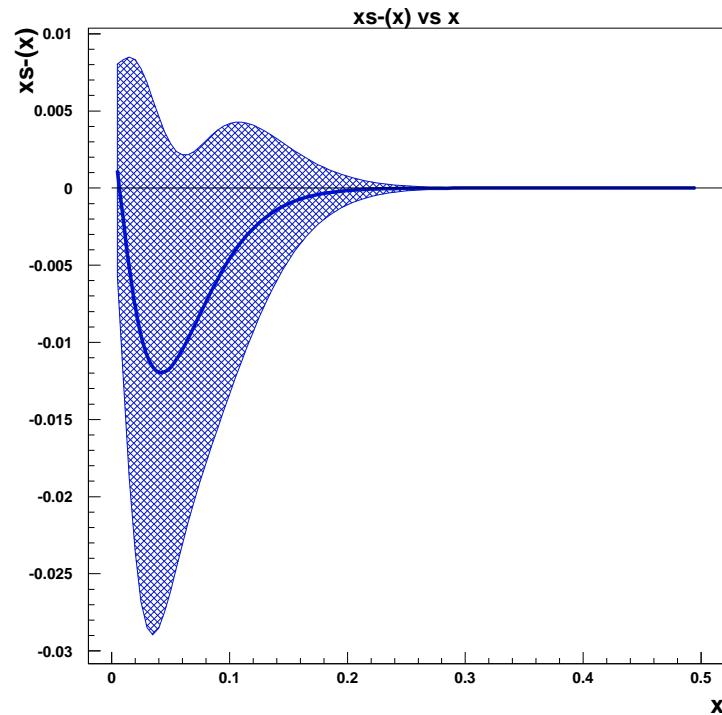


David Mason: Moriond QCD 2004
dmason@jeckyll.uoregon.edu



Asymmetry with New Parameterization

- Still leans toward negative asymmetry at low x
- Still consistent with zero
- $s^-(x)$ prefers satisfying sum rule by spiking positive below lowest x data point
- $\chi^2 = 37/37$ NDF



$$\int xs^-(x)dx = -0.0009 \pm 0.0014$$

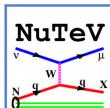
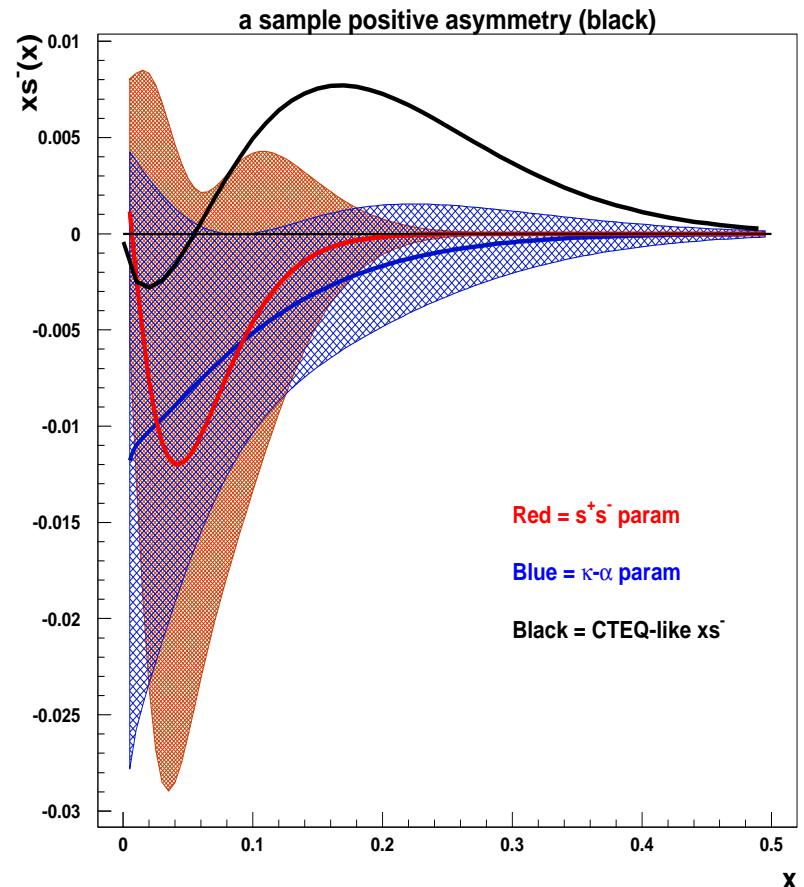


David Mason: Moriond QCD 2004
dmason@jeckyll.uoregon.edu



What About a Positive Asymmetry?

- Several global fits claim positive asymmetry, which has electroweak implications.
NuTeV can address this directly.
- Try constraining s^- to be positive
- Black curve is similar s^- to CTEQ with $\int xs^-(x)dx = 0.0016$
- High $\chi^2 = 55/40$ NDF (compared to 37/37 NDF)
- Positive asymmetry at higher x even more difficult



David Mason: Moriond QCD 2004
dmason@jekyll.uoregon.edu



What We Can Say Then...

- LO $\int xs^- dx$ with CTEQ5L consistent with zero
- NLO $\int xs^- dx$ with CTEQ6M consistent with zero
- We see negative tending s^- at low x
- Positive asymmetry difficult to accomodate, esp. at high x

